

***Ecology and Life History  
of Peirson's Milkvetch in the  
Algodones Dunes, California  
2003- 04***

**Arthur M. Phillips, III, Ph. D.  
Debra J. Kennedy**

**Botanical and Environmental Consulting  
P.O. Box 201 \* Flagstaff, AZ 86002**

**FINAL REPORT  
PREPARED FOR THE  
AMERICAN SAND ASSOCIATION  
AUGUST 2004**

## TABLE OF CONTENTS

INTRODUCTION .....	4
Species description and ecology .....	5
METHODS .....	5
Study area .....	6
Survey methodology.....	7
RESULTS AND DISCUSSION .....	10
Survival .....	10
October 2000 cohort .....	10
February 2003 cohort.....	11
2003-04 germination events.....	11
Climate, Reproduction and Survival.....	15
CONCLUSIONS.....	17
REFERENCES CITED.....	18
APPENDIX A – Data summary table.....	19
APPENDIX B – Associated Species .....	20
APPENDIX C – April 2004 field data form .....	21
APPENDIX D – March 2004 field data form .....	22

## LIST OF FIGURES, TABLES AND PLATES

Figure 1 – Study area map showing plant distribution and sample sites .....	6
Table 1 – Survival of 2000 & 2003 cohorts.....	10
Table 2 – Germination events, 2003-04 season .....	12
Table 3 – Climatic data, May 02 – May 04 .....	15
Table 4 – Seedpod production, 2001-04 .....	16
Plate 1 - Seedlings, March 2004 .....	13
Plate 2 - November 2003 plant flowering, March 2004 .....	14
Plate 3 - Perennial plant .....	14

## ACKNOWLEDGMENTS

The authors would like to acknowledge the invaluable assistance of the many members of the American Sand Association who provided transportation and support with their personal sand vehicles, shared their knowledge of the dunes, and assisted in many other ways. Otto and Vicki Privette were always there to help us; we owe them a great debt of gratitude, for the project would have been impossible without their help. Peter Haan drove for us on every trip this year, and was an expert PMV counter as well. Others to whom we are indebted for providing transportation included Dick Holliday, Rick Bowen, Don Techon, Kim McMillin, Steve Wark, and Troy Bierfeldt. Richard Bender provided a loaner sand rail that we used on every trip. Russ Borman, transportation chair for ASA, assisted with arranging transportation. Grant George, ASA president and Biology Committee chair, was responsible for the ASA oversight of the project and helped in many ways. Greg Gorman, Chairman of the ASA Board of Directors, provided encouragement and assistance whenever we called on him. Our deepest gratitude is expressed to all.

Chris Knauf and Greg Thomsen, Bureau of Land Management El Centro Resource Area, issued our research permits and assisted in numerous ways. Glenn Rink, Dede Weage, Dr. Barbara Phillips, and Terry Weiner assisted with the fieldwork. Dr. J. Mark Porter, Rancho Santa Ana Botanic Garden, and John Willoughby, BLM California State Office, Sacramento, engaged with us in helpful and elucidating discussions on the ecology of *Astragalus magdalenae* var. *peirsonii*. To all, we express our sincere thanks. This project was funded by the American Sand Association, the Off-Road Business Association, and the San Diego Off-Road Coalition.



Photos by A. M. Phillips, III

## INTRODUCTION

The Algodones Dunes are a complex of sand dunes located in Imperial County, California. They support a specialized, limited biota that has adapted to the severe conditions posed by an ever-changing habitat with low, unpredictable rainfall and severe annual and diurnal extremes in temperature. Many of the plant species found in the dunes are endemic to sand dunes in the Lower Colorado Valley subdivision of the Sonoran Desert (Bowers 1986; Shreve 1964). One of them, *Astragalus magdalenae* var. *peirsonii* (Peirson's milkvetch), listed as a Threatened species in 1998 (USFWS 1998, CNPS 2001, BLM 2000a).

Responding to wet conditions during the fall of 2000, Peirson's milkvetch underwent an explosive germination event in the spring of 2001, presenting a rare opportunity to examine the plant's life history and current and status.

We began a study of the ecology, demography, and life history of *A. m.* var. *peirsonii* from early March to mid-May 2001, surveying the Algodones Dunes system and collecting and analyzing population, reproduction, distribution and habitat data, including a census of plants and descriptive survey of the plant's ecology within the dune system. The results were presented in the "Olsen Report" prepared by Phillips et al. (2001). From November 2001 to February 2002, under a contract from the American Sand Association with A. M. Phillips, III, the second year of the study included analysis of the seed bank of Peirson's milkvetch, along with an assessment of the survival of the cohort of plants censused in the spring of 2001 at 25 randomly selected sites, a 40% sample of the 2001 sites. The results were presented in a comprehensive report summarizing the first two years of the study that estimated the total seed bank for 60 sites at between 2.5 and 5.8 million seeds and documented a 21% survival rate of the 2001 cohort (Phillips and Kennedy 2002).

Continuing the study to year three, we visited the 25 sites sampled in 2002 in March 2003 to ascertain survival of the 2000 cohort of plants to a third season. A series of storms in late February 2003 caused another germination event, with thousands of seedlings appearing in early March. The 2003 germination differed from the 2000 event in that it occurred late in the growing season, providing an opportunity to compare the success of germination events occurring at different times in the growing season. We returned in April and May 2003 to determine the magnitude of this event and its likely reproductive success. The results of the survival inventory and the germination survey were presented in Phillips and Kennedy (2003).

We began the fourth year of the study in October 2003, with an early-season visit to ascertain survival of the remaining 2000 plants and the February 2003 cohort through the summer. At that time the heat of summer was still in control, and no recent rains had occurred, so it was not possible to accurately assess survival. We returned in December when cool season conditions had returned, and in addition to survival we were able to document a mid-November germination event. In early March we again visited the 25 sites and found seedlings that were germinating in response to a late February rain. We returned again in April, after another storm, to summarize the success of the 2003-04

germination events and determine if rain as late as April can result in germination. The results of Year 4 of the study are presented here.

### *Species Description and Ecology*

*Astragalus magdalenae* var. *peirsonii* is a member of the Legume Family (Fabaceae). The seeds are the largest of any North American species of *Astragalus* (Barneby 1964, Felger 2000), and the pods generally ripen in May and June.

Although *A. m.* var. *peirsonii* is considered to be a short-lived perennial (Barneby 1964) or “ephemeral” (Felger 2000), suggesting its facultative perennial nature, it is well adapted to flower and produce seeds during its first year (Phillips et al. 2001). The pods produced by Peirson’s milkvetch are strongly inflated, and can blow across the surface of the dunes until they lodge against a shrub or in a swale with reduced wind velocity (Bowers 1986). However, the distal end of the pod splits open prior to falling from the parent plant, allowing the seeds to be released essentially in place, and causing many pods to fill with blowing sand and become anchored before they can be blown very far. Thus they can be transported from one favorable site to another, or remain near the parent plant, depending on winds. Many pods shed their seeds near the parent plant, replenishing the seed bank where the parent plant grew.

The most detailed discussion of Peirson’s milkvetch ecology is found in Barneby (1964, as summarized in Phillips and Kennedy (2003).

In addition to the Algodones Dunes, Peirson’s milkvetch also occurs in the Gran Desierto dunes of northwestern Sonora, Mexico (Felger 2000). *Astragalus magdalenae* var. *peirsonii* is not known to exist in Arizona, as reports that the species occurs in the Yuma Dunes of southwestern Arizona were based upon a misidentified specimen (Phillips and Kennedy 2002).

## **METHODS**

During the 2003-04 winter season we conducted a fourth year of our study of Peirson’s milkvetch in the Algodones Dunes. This provides a fourth consecutive year of data on the ecology and life history of the species. As previously stated, the purpose of our investigation was to collect and analyze population, reproduction, survival and seed bank data in order to assess the biology and status of *A. m.* var. *peirsonii* in the Algodones Dune system. Stage one of the study was conducted from early March to mid-May 2001 and included a descriptive survey of the plant’s demography and ecology within the dune system. Stage two was conducted from November 2001 to February 2002 and included a sampling of the Peirson’s milkvetch population surveyed in stage one in which survival and seed bank data were collected and analyzed. Stage three was conducted from March to May 2003 and included a survey of plant survival and reproduction of the population sampled in stage two of the study, and initial inventory of a new cohort that germinated in February 2003.

Stage four was conducted from October 2003 to April 2004 at the same sites studied in 2002 and 2003, and includes survival tracking of the 2000 and 2003 cohorts, and documentation of two additional new germination events.

## Study Area

The Algodones Dunes, located in southeastern Imperial County, California and extending a short distance into adjacent Baja California, Mexico, are about 65 km (40 miles) in length, trending from northwest to southeast, and from 5 to 10 km (3 to 6 miles) wide (see Figure 1 below). The total area of the dune system includes approximately 60,705 ha (150,000 acres), of which 12,950 ha (32,000 acres) are designated as a wilderness area (BLM 2000b). Off-highway vehicle (OHV) recreational use of the dunes has occurred for many decades; it has seen a large increase in popularity in the past 25 years, and in the past ten years use levels have mushroomed along with the introduction of a wider variety of vehicles of increasing sophistication. Although some have

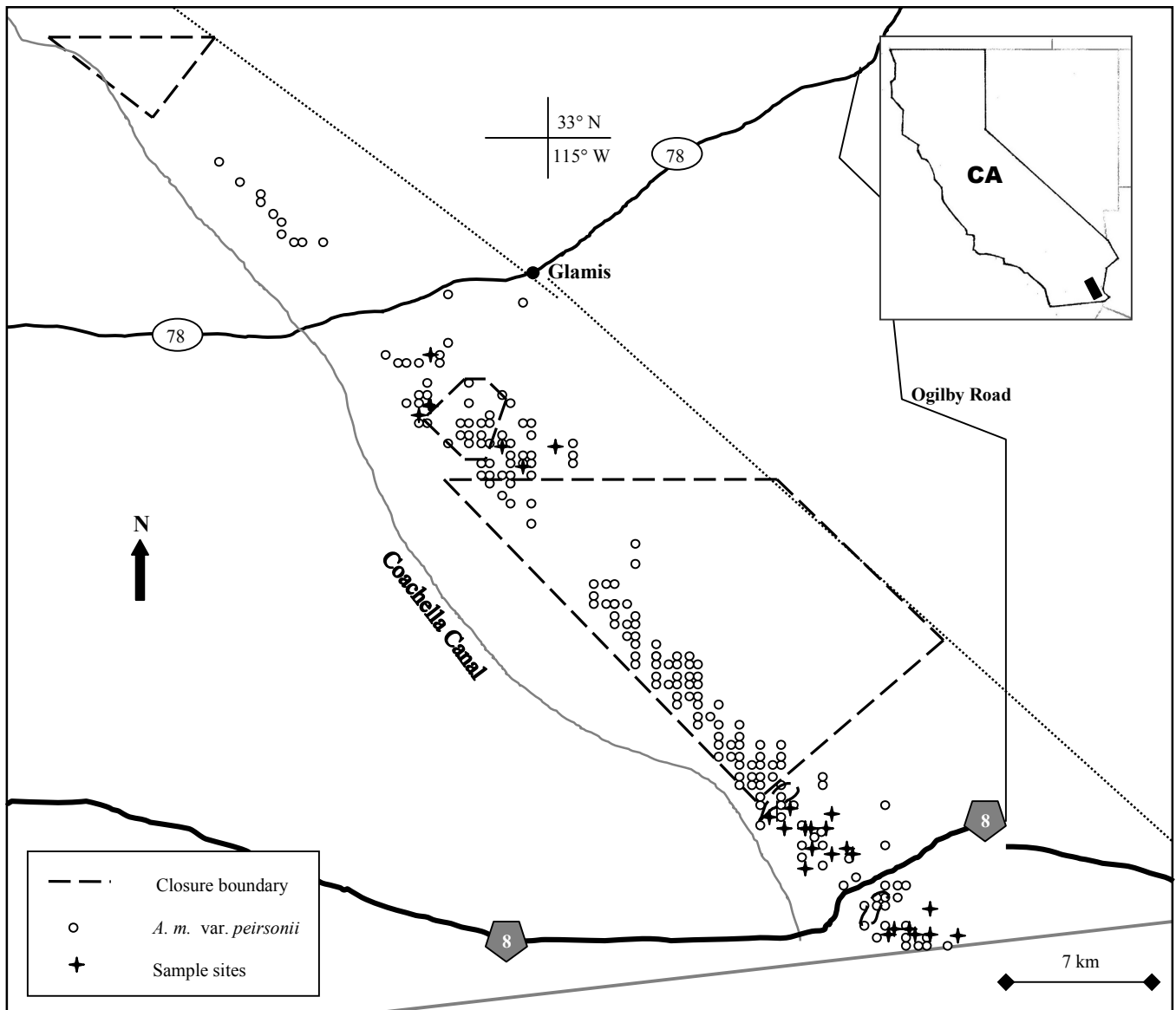


Figure 1. Location of *Astragalus magdalenae* var. *peirsonii* sites in the Algodones Dune system surveyed in spring 2001, sampled in winter 2001-02 and surveyed again in 2003-04<sup>1</sup>

<sup>1</sup>Site locations are approximate; see Phillips et al. (2001) Appendix A for exact geo-coordinates. Locations within closures were mapped by helicopter survey.

speculated that increasing levels of OHV use within the dune system negatively affects the status of *A. m. var. peirsonii*, no empirical study focusing on the effects of OHVs on Peirson's milkvetch and other plants and animals in the dune system has been completed.

An overview of the geologic history and setting of the Algodones Dunes is provided by Norris and Norris (1961). The system consists of a complex chain of overlapping barchan dunes, with the higher dunes rise 60-90 m (200-300 feet) above the desert floor. From west to east a series of sand ridges along the western edge gradually transitions to the highest, most active dunes, generally the main focal point of OHV recreation, in the eastern half of the system. Between the ridges and the high dunes are a series of lower bowls and ridges, which support the highest levels of vegetation density, including Peirson's milkvetch. Our initial survey, in 2001, covered the entire dune system. Our subsequent studies have been focused on areas where the occurrence and density of the plants is greatest.

### *Survey Methodology*

To evaluate the distribution, reproductive capabilities and habitat requirements of *A. m. var. peirsonii* during stage one of our study, we employed a number of observational techniques. Statistical sampling methods were not included in this stage of the investigation, since the purpose of the descriptive survey was to locate as many occurrences of the subject plants as possible, and to completely census and collect reproductive and habitat data from every area in the dune system in which they were found.

A preliminary reconnaissance was conducted in 2001 from the U.S.–Mexico border north to California Highway 78 (the southern boundary of the wilderness area) covering approximately 14,165 ha (35,000 acres), or 59% of the open area of the dune system. From data collected during the preliminary reconnaissance, we determined that *A. m. var. peirsonii* generally occurs in highly clustered, specialized habitats within the dunes, and that a large portion of the dune system (approximately 70-75%) does not contain habitat suitable for these plants. Using data gathered from the reconnaissance and informant interviews, along with our specific knowledge of habitat requirements, we selected several survey areas that were intensively searched for the presence of the subject plant.

When *A. m. var. peirsonii* plants were present in a survey area, it was designated a “site,” a number was assigned to that area and a complete census of plants was conducted. The location of each site was recorded with a Global Positioning System (GPS) unit, which was also used to circumscribe the boundary of the site.

Any area of occurrence that was too small to circumscribe, or that contained a single cluster of *A. m. var. peirsonii*, was designated a “point.” The plants contained within a point were also counted and the location was recorded with the GPS unit. Utilizing this methodology, we identified 60 sites and 66 points of milkvetch occurrence, and surveyed a total of 71,926 plants during the first year of the study. Of these, approximately 45% were determined to be reproductive. Both site and point data were mapped and entered into a master database (Phillips et al. 2001, Appendix A).

An aerial (helicopter) reconnaissance of the 20,000 ha (49,000 acres) within the three temporary closure areas and the wilderness area allowed us to map the distribution of Peirson's milkvetch utilizing the GPS unit. No census of plants was possible from the air but 185 points of milkvetch occurrence were mapped (see Phillips et al. 2001, Appendix B).

Stage two of the study was conducted from November 2001 to February 2002 and included an analytical sampling of the *A. m. var. peirsonii* population in which survival and seed bank data were collected and analyzed. Utilizing plant distribution data gathered during stage one, we determined that a stratified random survey design best suited the population under study. Prior to conducting the fieldwork for this stage of the investigation, we stratified the dune system into three locations. Location 1 encompassed most of the open area of the dune system south of Interstate 8 and north of the international border, known as the Buttercup area. Location 2 included the area north of Interstate 8 and south of the large central closure (Patton Valley). Location 3, in the northern region of the system, included the open area from south of Highway 78 and east of Gecko Road to the northern boundary of the large central closure.

The data collected during stage one of the study showed a high degree of non-random distribution of Peirson's milkvetch within the dune system; i.e., the plants were distributed in particular similar locations, and clustered within the habitats where they were found. In order to account for distribution variance and adequately represent the target population, we randomly selected 40% of the areas designated as sites during the first stage of the study for sampling in stage two. Seven sites were selected in location 1, twelve in location 2 and six in location 3, for a total of 25 sample sites.

Analysis of the soil seed bank was the focus of stage two of the study. The purpose was to provide an estimate of the number of seeds in the seed bank in order to assess the potential status of the population, and to determine patterns of spatial and temporal seed distribution. We extrapolated the seed bank data to the number of milkvetch identified and surveyed at 60 sites in stage one of the study and determined that the soil seed bank consisted of approximately 2.5 million (extrapolated to number of reproductive plants only) to 5.6 million (extrapolated to total number of plants) *A. m. var. peirsonii* seeds.

In addition to seed bank data, at each selected site we repeated the census of the plants surveyed during stage one of our study, in order to determine how many had survived through the summer of 2001. We determined that survival rate of the 2000 cohort to winter 2001-02 was approximately 21% -- an extraordinarily high rate, since only five of the initial 71,000 milkvetch surveyed in stage one had survived from the previous year. The results were analyzed and presented in Phillips and Kennedy (2002).

Third-year surveys were conducted from March to May 2003 and included a third-season survey of survival and reproduction of the 2000 cohort of plants at the 25 sites, and inventory of the sites to census a new cohort of seedlings that germinated in late February 2003. The results of the third year of our Peirson's milkvetch study were presented in Phillips and Kennedy (2003).

Our fourth study season started in mid-October 2003, when we visited the sites to determine summer survival. We determined that this was too early; plants had not yet resumed growth following summer dormancy. We returned in December to assess survival and count seedlings from a November germination event at the 25 sites. In March 2004 we documented a February 2004 germination, and counted the November cohort survivors. Our last trip for the season was in April, when we noted the effects of an early April storm on germination and again censused the November and March germinants, as well as perennial survivors from prior years.

At each visit, the inventory was conducted in the same manner as in previous years: upon arrival at a site the boundaries were determined using the GPS unit and site diagrams that were prepared in 2003, participants were advised of the site boundaries, and the site was divided into sectors for counting plants. Because the seedlings were tiny and several people participated at all sites, counters made an arc in the sand with a pole to mark plants or clumps when they were counted. Notation was made of reproductive status of seedling and adult plants. Age class of first-year plants was tallied where possible (see Discussion, below). The counts were then reported to a team leader and recorded before advancing to the next site (see Appendix D for an example of the field data form).

## RESULTS AND DISCUSSION

The 2003-04 surveys followed the survival and reproduction of the remaining plants of the 2000 cohort and the cohort that germinated in February 2003. Two additional germination events occurred and were documented during the season, one following a relatively minor rainfall event in November 2003 and another after a mid-February 2004 storm. The largest storm of the year, in early April, resulted in no germination of Peirson's milkvetch.

### *Survival*

The question of the longevity of Peirson's milkvetch plants is important in several respects. First, it indicates whether living plants survive between germination events, or whether the species survives by relying on a seed bank of long-lived seeds that remain dormant in the soil between occurrences of favorable conditions for germination. Second, it is essential in determining whether the status can be determined by surveying for living plants, or whether the seed bank must also be included in an assessment. Finally, it is an essential element in developing a life history of the species.

	<i>October 2000 Cohort</i>					<i>Feb. 2003 Cohort</i>		
	# Plants	Survivors	Survivors	Survivors	Survivors	# Seedlings	Survivors	Survivors
Area	Spring 01	Spring 02	Spring 03	Dec. 03	Mar. 04	Spring 03	Dec. 03	Mar. 04
Buttercup (7 sites)	13,373	2,291	32	1	1	12,180	0	0
Patton Vly (12 sites)	16,749	3,873	37	8	6	20,643	10	8
Glamis (6 sites)	729	248	14	3	1	296	6	4
Totals	30,851	6,412	83	12	8	33,119	16	12
% Survival		21%	0.27%	0.04%	0.03%		0.05%	0.04%

Table 1. Initial census and subsequent survival of October 2000 and February 2003 cohorts of Peirson's milkvetch, through March 2004.

### October 2000 Cohort

Table 1 summarizes the survival of the October 2000 cohort, which was first inventoried in March and April, 2001. The initial census at the 25-site subsample for this cohort was 30,851 plants, including some which germinated in March 2001. Survival through the first summer was 21%, then dropped dramatically to 0.27% by the second season. They were counted twice during the 2003-04 season, and only 8 of the original plants survived in March 2004. Four plants died between December 2003 and March 2004, during the growing season. The cause was not always evident; some toppled from loss of sand around the roots, others were dead but the cause was not evident, and some were missing. While some of the original plants were still alive after four seasons, the length of time in which they made a significant contribution to the seed bank was limited to their first two seasons.

## February 2003 Cohort

The life history of the February cohort was quite different from that of the 2001 plants. Although more plants were initially counted in February 2003 at the 25 sites, their history differed in several important ways. First, they did not flower during their first season. Apparently plants that germinate in late winter do not have enough time to complete a reproductive cycle before entering summer dormancy, so their growth remains vegetative. Second, their survival rate to a second season was very low: only 12 individuals, or 0.04%, of which only four ultimately flowered.

The question of differentiating between first-year plants and perennials (i.e., those that have survived at least one summer, or dormant, season) has been raised on several occasions. Peirson's milkvetch is not unlike many other herbaceous plant species in the morphology of perennial plants. The leaves of the plant are deciduous, as are the green branches of a given year. These die during the summer, and often become broken off. Second-year branches originate at or near the base of the plant, and grow rapidly in large numbers in the fall on a healthy plant. The broken stems from the first year remain obvious around the base of the plant. Also, first-year plants consist of one or few upright stems, so the plant is taller than wide. Perennial plants, with numerous stems originating from the base, are generally round in outline. The diameter of the root, when exposed by pedestaling, is another indication of age; it is generally 2 cm or more in perennial plants, and less than 1 cm in first-year plants. Thus, with a little practice it is not difficult to distinguish first-year plants from second-year or older plants using many of the standard characters that botanists use for a wide range of forbs and grasses. The morphology of first-year plants that germinate in the fall is consistent with that of late-winter germinating plants, except that the fall germinants are capable of flowering during their first year.

Determining the age of perennial plants becomes somewhat more difficult. By the late spring of 2004 it was often difficult to distinguish perennials that originated in 2000 from those that germinated in February 2003. They both had a similar morphology and were similarly fecund. Site differences and individual variation in plants were greater than any consistent factors allowing us to age plants. We were certain that no plants at any of our sample sites were older than 2000 because no perennial plants were found there in 2001.

## 2003-04 Germination Events

Rainfall events in mid-November 2003 and late February 2004 produced both late fall and late winter Peirson's milkvetch germination events during the 2003-04 growing season (Table 2). This provided an opportunity to compare the phenology of plants germinating at different times during the same season.

The November germinants were observed during a trip to the dunes December 18-20, 2003, about five weeks after a rainfall event on November 12<sup>th</sup>. This was not a major storm; the Buttercup RAWS weather station recorded 0.26 inches, and the Cahuilla station recorded 0.11 inches. Seedlings were noted in all three areas, and damp sand was

present within 4-6 inches of the surface. Of course it is possible that heavier rainfall occurred at our sampling sites than was recorded at the weather stations.

We made several important observations during the December visit. First, seedling milkvetches retain their cotyledons for some time after germination. The large, thick, dark green seed leaves allow for the rapid elongation of the roots before much energy is invested in true leaves. The first leaves are similar to later ones: small, gray-green leaves with tiny leaflets on an elongated rachis. The ability to invest initial energy in root elongation is an adaptation minimizing the danger of early desiccation.

The answer to the question of whether seeds lying on the surface of the sand can germinate or whether they must be buried; and if subsurface seeds germinate, how deep they can be buried and still germinate, has been elusive. The answer appears to be both. Some seeds just germinating were found that had been lying on the surface. Others were found that appeared to have germinated from shallow depths. How deep they can be, the proportion that germinate at or below the surface, and the later success of seeds germinating on the surface compared with those that are buried remains unknown. Our seed bank study (Phillips and Kennedy 2002) found more seeds on the surface than buried, and observation of seeds on the surface in 15-20 mph winds suggested that sand grains tended to blow over the large, flat seeds leaving them on the surface. The optimal location for germination and behavior of seeds in blowing sand is a topic that requires more investigation before we can provide definitive answers.

	# Nov. 03 Seedlings	# Nov. 03 Plants	# Feb. 04 Seedlings	# Nov.03- Feb..04 Sdl.	#Nov. 03 Sdl. Reproductive.	# New Seedl.
Area	Dec. 03	Mar. 04	Mar. 04	Apr. 04	Apr. 04 R	Apr. 04
Buttercup (7 sites)	5468	2548	180	2884	1	0
Patton Vly (12 sites)	6708	3712	509	6478	0	0
Glamis (6 sites)	170	445	5	486	5	0
Total	12,346	6705	694	9848	6	0
		54.30%		75.50%	0.05%	

Table 2. Germination events occurring during the 2003-04 growing season.

The initial February germination event was much smaller than November, with only 6% as many seedlings, even though the rainfall amounts were greater (0.55 inches at Buttercup, 1.21 inches at Cahuilla). The field work was carried out March 5-8, about two weeks following the storm. The amount of rain recorded was comparable to the storm that occurred in mid-February 2003, yet the number of seedlings recorded, 694, was a tiny fraction of the 33,119 seedlings that germinated in 2003. Clearly there is not a simple correlation between rainfall amount and the magnitude of germination events.

Our counts during the April 15-17 visit provided another surprise. In all three areas the number of seedlings counted was greater than the sum of November 2003 and February 2004 seedlings counted in March. Apparently additional germination had occurred in the five weeks between these visits. Germination appears to occur over a period of time rather than as a single flush immediately following rains. It seems likely that seeds germinating some period of time after a rain probably are buried rather than on the surface; the surface of the dune dries out rather quickly after a rain, insulating the

subsurface area, which can retain moisture much longer, for weeks at a depth of a few inches.

Another unanticipated situation arose during the April trip. We were unable to distinguish between seedlings that had germinated in November and those that had germinated in March. At all sites there was a continuum of sizes of plants, with no clear differentiation into two size classes. Apparently microsite conditions such as moisture availability and sand deflation rapidly become more important than age in determining size of plants.

This also sheds some light on the situation we encountered during our initial survey in 2001. We stated that some of the plants we counted during our April and May visits had apparently germinated following early March storms rather than the previous October, but we did not see any clear differentiation. Now we know why: after a few weeks the age of plants of the season can not be accurately determined, as long as they are sterile. The February 2003 cohort (not complicated by plants germinating earlier that season) showed that late winter plants do not flower their first year. They can grow to robust plants up to 12 inches tall, and have the morphology of first-year plants that flower at smaller sizes, but produce no flowers. On the other hand, some November 2003 plants flowered in March and April 2004 but were otherwise indistinguishable from sterile plants of the same season. It should be emphasized that first-year flowering plants are easily distinguishable from second-season and older plants using the perennating characteristics described previously.



Plate 1. Seedling Peirson's milkvetch just starting to develop first leaves.



Plate 2. November 2003 milkvetch flowering in March 2004



Plate 3. Perennial plant, probably from 2000, in the Glamis area, March 2004.

## Climate, Reproduction and Survival

The link between climatic events and germination, reproduction, and survival of Peirson's milkvetch has been a primary area of investigation since the start of this project in the spring of 2001. The climatic link between the explosive germination event of *A. m. var. peirsonii* in the fall of 2000 and rainfall was examined by Phillips et al. (2001). During the first year, it was necessary to utilize remote weather records to correlate germination with precipitation. However, the installation of two RAWS stations in the dunes in November 2001, at Buttercup and Cahuilla Ranger Station, has allowed a much more accurate estimate of rainfall within the dune system. Rainfall records from May 2002 through May 2004 are shown in Table 3.

Date	Precipitation (in.)		#Days	Max	Date	#Days	Max	Date
	Buttercup	Cahuilla						
May 02	0	0	0		-	0		-
Jun. 02	0	0	0		-	0		-
Jul. 02	0	0	0		-	0		-
Aug. 02	0	0	0		-	0		-
Sep. 02	0.25	0.82	1	0.25	10th	3	0.76	10th
Oct. 02	0	0.06	0		-	1	0.06	26th
Nov. 02	0	0.03	0		-	3	0.01	27, 29, 30
Dec. 02	0	0.01	0		-	1	0.01	1st
Jan. 03	0.01	0	1	0.01	8th	0		-
Feb. 03	0.81	1.26	3	0.41	12th	4	0.57	12th
Mar. 03	0.08	0.50	2	0.05	15th	2	0.32	16th
Apr. 03	0	0	0			0		
May 03	0	0	0		-	0		-
Jun. 03	0	0	0			0		
Jul. 03	0.03	0.06	1	0.03	28th	1	0.06	30th
Aug. 03	0.36	0.63	2	0.31	24th	3	0.46	24th
Sep. 03	0	0	0			0		
Oct. 03	0	0	0			0		
Nov. 03	0.26	0.11	1	0.26	12th	1	0.11	12th
Dec. 03	0	0.01	0			1	0.01	25th
Jan. 04	0.11	0.05	2	0.09	22nd	1	0.05	20th
Feb. 04	0.55	1.21	1	0.55	23rd	4	1.15	22nd
Mar. 04	0.20	0.23	2	0.18	2nd	2	0.14	2nd
Apr. 04	1.34	0.59	1	1.34	2nd	2	0.58	2nd
May 04	0	0	0			0		

California Dept. of Water Resources (2003, 2004)

Table 3. Climate data for Buttercup (location 1) and Cahuilla (location 3), May 2002 – May 2004

The heaviest rainfall amounts of the 2003-04 season fell in early April at Buttercup, with 1.34 inches recorded on April 2<sup>nd</sup>. Cahuilla recorded 0.59 inches, about half as much as in the February event. From our experience earlier in the season, our visit from April 15-17 should have been at the right time to find any resulting seedlings. In

fact, we found not a single new germinant in mid-April. We conclude that April is late enough in the season that higher temperatures are occurring, and germination is inhibited. This would certainly be advantageous for the plant, because seedlings that germinate in April would not have time to develop a root system sufficient to allow them to survive the summer. Previous observations (Phillips et al. 2001, Phillips and Kennedy 2002) have indicated that germination does not occur after summer or September rains. The April data corroborates previous observations that Peirson's milkvetch is a cool-season species in terms of germination as well as growth and reproduction.

While there is clearly a relationship between precipitation and germination during the cool season, the 2003-04 field work showed that the correlation is not necessarily predictable in terms of the amplitude of the germination event and the amount of precipitation. As noted above, the November storm, leaving one-half to one tenth as much rain as the February storm, resulted in an 18-fold greater germination event. When delayed germination is factored into the February event, the difference is four-fold. On the other hand, the February 2003 event produced more seedlings (33,119) than all of the events combined in 2000-01 (30,851) at the 25-site subsample. Thus it can be concluded that there is a correlation between rainfall and germination, but the relationship between amount of precipitation and magnitude of germination is not directly proportional. Other factors, not measured during this study, are apparently at work, such as temperature, soil moisture, seed germination inhibitors, and perhaps even daylength.

#### *Variation in Seed Production*

The relative contribution to the seed bank by plants of various ages has been a topic of some debate and confusion. The answer is that it varies from year to year depending on the age structure of the reproductive population. Table 4 presents an estimate of relative seed bank contribution over the four-year period of this study.

	2001	2002	2003	2004
First-year plants	69,615	0	0	30
Perennial plants	0	1,096,452	14,193	3420

Table 4. Seedpod production by first-year reproductive plants and perennials at 25 sites. Assume production of 5 pods per plant by first-year plants and 171 pods per plant by perennials. Assume 100% of perennials are reproductive.

The assumed average production of 171 pods per perennial plant is based upon a small sample of plants at one site (Phillips and Kennedy 2003) and does take into account sterile plants or those that produce few pods. Pod production by second-year plants in 2002 is 16 times the production by first-year plants in 2001, but by the third year the 2001 contribution by first-year plants is five times greater than the production of third-year perennials in 2003, and by 2004 it is 20 times greater. There were five perennial plants found during the spring 2001 survey, but they were not in a site included in the 25-site subsample so they are not included in Table 4. From this summary it is apparent that the number of seeds produced varies widely from year to year, and the relative contribution of first-year reproductive plants and perennials depends on the year.

## CONCLUSIONS

It has become apparent during the four years of our study that Peirson's milkvetch exhibits an unusual dual reproductive strategy. Plants that germinate in the fall, often in response to rare subtropical Pacific moisture climatic events, are capable of reproducing during their first season at levels of at least 45%. Survival of these plants through the ensuing summer season was documented at 21% for the single cohort that exhibited these characteristics, that of October 2000. The second strategy is late winter germination, in February and March, which may equal the fall germination in numbers of plants produced. However, late winter germinants are unable to reproduce during the short remainder of the growing season and put their energy into developing a root system sufficient for surviving the summer season, which apparently is achieved by very few of the seedlings. In December 2003 the survival rate of February 2003 seedlings was 0.05%, or 16 individuals out of 33,119 germinants, a high cost germination event in terms of survival.

This is a big loss of seeds from the seed bank, and changes our initial impression that Peirson's milkvetch is relatively conservative in producing only seedlings that were likely to succeed in producing progeny. However, if all of the 16 survivors of the February 2003 cohort reproduced with an average of 171 pods producing 14 seeds per pod they would produce over 38,000 seeds, more than replenishing the 33,000 seeds that germinated during its second season. The seed bank reserves are sufficient to allow for germination events to occur in "risky" situations, and the fecundity of the plants producing large numbers of seeds makes it possible for just a few survivors to replenish the seed bank.

We repeat our assertion that determination of the status of a desert ephemeral or short-lived perennial must include an assessment of the seed bank and its characteristics as well as the actively growing plants. It is not an easy task to assess the health of short-lived desert plants because their numbers are so variable from year to year, and so much of their potential is included in dormant seeds. All data collected over a four-year period indicate that Peirson's milkvetch is a healthy species surviving the effects of a highly variable climate and potential impacts from OHVs without the need for protection or intervention.

## REFERENCES CITED

- Barneby, R. C. 1964. *Atlas of North American Astragalus*. Memoirs of the New York Botanical Garden 13: 858-863.
- BLM. 2000a. Monitoring special status plants in the Algodones Dunes, Imperial County, California. Results of 1998 monitoring and comparison with the data from WESTEC's 1977 monitoring study. Report prepared by Bureau of Land Management, California State Office, Sacramento, CA, Nov. 2000.
- BLM. 2000b. Map of Imperial Sand Dunes Recreation Area. Prepared by Automobile Club of Southern California.
- Bowers, J. E. 1986. *Seasons of the wind*. Northland Press, Flagstaff, AZ. 156 p.
- California Department of Water Resources. 2003, 2004. Historic precipitation records for Buttercup and Cahuilla weather stations. [http://cdec.water.ca.gov/cgi-progs/plotReal?staid=CAU&send\\_date=now](http://cdec.water.ca.gov/cgi-progs/plotReal?staid=CAU&send_date=now). Electronic document, accessed 28 May 2003 and 18 August 2004.
- CNPS. 2001. *Inventory of rare and endangered vascular plants of California*. 6<sup>th</sup> ed. California Native Plant Society Press, Sacramento, CA.
- Felger, R. S. 2000. *Flora of the Gran Desierto and Rio Colorado of northwestern Mexico*. The University of Arizona Press, Tucson, AZ. 673 p.
- Norris, R. M. and K. S. Norris. 1961. Algodones Dunes of southeastern California. *Geological Society of America Bulletin* 72: 605-620.
- Phillips, A. M., III, D. J. Kennedy, and M. Cross. 2001. Biology, distribution, and abundance of Peirson's milkvetch and other special status plants of the Algodones Dunes, California. Report submitted by Thomas Olsen Associates, Inc. to the American Sand Association. 29 p.
- Phillips, A. M., III and D. J. Kennedy. 2002. The Ecology of *Astragalus magdalenae* var. *peirsonii*: Distribution, reproduction and seed bank. Report submitted to the American Sand Association. 41 p.
- Phillips, A. M., III and D. J. Kennedy. 2003. The Ecology of *Astragalus magdalenae* var. *peirsonii*: Germination and survival. Report submitted to the American Sand Association. 27 p.
- Shreve, F. 1964. Vegetation of the Sonoran Desert. IN: Shreve, F., and I. L. Wiggins. *Vegetation and flora of the Sonoran Desert*. Stanford University Press, Stanford, CA. Vol. 1, Part 1.
- U. S. Fish and Wildlife Service. 1998. Determination of status for five plant taxa from California: ... Peirson's milkvetch ... Final Rule. *Federal Register* 63(193): 53598-53615. Oct. 6, 1998.

Appendix A Summary of 2003-04 field studies.

**PMV Study Sites - 2003-04**  
**Algodones Dunes (ISDRA), California**  
**A. Phillips**

(P = Present, R = Reproductive)

Site No.	Loc.*	Area m <sup>2</sup>	# Plants Spring 01	# Seedlings Apr.-May '03	# Seedlings Dec. 03	# Per. Plts Mar. 04	# Feb. 03 Plts Mar. 04	# Nov. 03 Plts Mar. 04	# Seedlings Mar. 04	# Per. Plts Apr. 04 P	# Per. Plts Apr. 04 R	# Feb. 03 Plts Apr. 04 P/R	# Nov.03- Mar.04 Scd.	#Nov. 03 Scd. Apr. 04 R	# New Seedl. Apr. 04	Site No.
6	1	1,007	340	0	20	0	0	0	0	0	0	0	0	0	0	6
7	1	15,709	3,127	6,621	4,000	0	0	1655	100	0	0	0	1465	0	0	7
21	1	15,876	1,327	634	150	0	0	6	20	0	0	0	82	0	0	21
22	1	6,995	807	131	175	0	0	9	50	0	0	0	49	1	0	22
23	1	7,908	2,800	535	123	0	0	3	5	0	0	0	26	0	0	23
28	1	4,653	978	617	600	1	0	441	0	1	0	0	530	0	0	28
29	1	7,182	3,994	3,642	400	0	0	434	5	0	0	0	732	0	0	29
32	2	14,854	657	1,273	400	5	0	376	0	4	4	0	747	0	0	32
34	2	22,604	1,534	1,597	130	0	0	69	46	0	0	0	85	0	0	34
41	2	4,206	120	1,112	400	0	0	104	0	0	0	0	546	0	0	41
44	2	76,236	798	74	3	0	0	17	2	0	0	0	105	0	0	44
46	2	16,251	1,531	3,097	2,700	0	1	1338	91	0	0	1 / 1	1646	0	0	46
47	2	17,624	2,530	1,401	1,200	0	0	540	52	0	0	0	585	0	0	47
48	2	17,335	1,037	706	25	0	4	216	0	0	0	0	289	0	0	48
51	2	22,173	1,898	1,987	1,000	0	0	423	10	0	0	0	778	0	0	51
52	2	68,775	3,010	2,557	500	0	0	122	6	0	0	0	214	0	0	52
53	2	63,556	1,090	1,327	200	0	0	137	0	0	0	0	140	0	0	53
54	2	6,798	577	969	50	1	3	120	300	0	0	1 / 0	501	0	0	54
57	2	16,089	1,967	4,543	100	0	0	250	2	0	0	0	842	0	0	57
13	3	32,154	230	127	50	0	0	229	5	0	0	0	272	4	0	13
15	3	7,581	28	11	10	0	0	0	0	0	0	0	0	0	0	15
16**	3	26,719	265	1	6	0	0	0	0	0	0	0	0	0	0	16**
19	3	329	77	85	100	0	3	215	0	0	0	3 / 3	214	1	0	19
60	3	1,573	88	70	2	1	1	1	0	0	0	0	5	0	0	60
61	3	1,424	41	2	2	0	0	0	0	0	0	0	0	0	0	61

\*Loc. 1 = Buttercup, Loc. 2 = Patton Valley, Loc. 3 = Gecko Rd. area

\*\* revised GPS location

30,851	33,119	12,346	8	12	6705	694	0	0	5 / 4	9848	6	0
			0.03%	0.04%	54.31%					51.69%	0.05%	
										(of Nov. 03 + Mar.04 scd.)		

Site	Loc.*	# Seedlings	# Nov. 03 Plts	# Seedlings	# Nov.03-Mar.04 Sdl.	#Nov. 03 Sdl.	# New Seedl.
No.		Dec. 03	Mar. 04	Mar. 04	Apr. 04	Apr. 04 R	Apr. 04
6	1	20	0	0	0	0	0
7	1	4,000	1655	100	1465	0	0
21	1	150	6	20	82	0	0
22	1	175	9	50	49	1	0
23	1	123	3	5	26	0	0
28	1	600	441	0	530	0	0
29	1	400	434	5	732	0	0
32	2	400	376	0	747	0	0
34	2	130	69	46	85	0	0
41	2	400	104	0	546	0	0
44	2	3	17	2	105	0	0
46	2	2,700	1338	91	1646	0	0
47	2	1,200	540	52	585	0	0
48	2	25	216	0	289	0	0
51	2	1,000	423	10	778	0	0
52	2	500	122	6	214	0	0
53	2	200	137	0	140	0	0
54	2	50	120	300	501	0	0
57	2	100	250	2	842	0	0
13	3	50	229	5	272	4	0
15	3	10	0	0	0	0	0
16**	3	6	0	0	0	0	0
19	3	100	215	0	214	1	0
60	3	2	1	0	5	0	0
61	3	2	0	0	0	0	0

12,346

6705

694

9848

6

0

54.31%

51.69%

0.05%

(of Nov. 03 +  
Mar.04 sdl.)

## Appendix B

<i>Associated Species</i>	<i>Common Name</i>
<i>Asclepias subulata</i>	Reed-stem milkweed
<i>Astragalus lentiginosus</i> var. <i>borreganus</i> *	Borrego milkvetch
<i>Croton wigginsii</i> * <sup>†</sup>	Wiggins' croton
<i>Dicoria canescens</i> <sup>†</sup>	Desert dicoria
<i>Ephedra trifurca</i>	Long-leaved joint-fir
<i>Eriogonum deserticola</i> <sup>†</sup>	Desert buckwheat
<i>Helianthus niveus</i> ssp. <i>tephrodes</i> * <sup>†</sup>	Dune sunflower
<i>Hilaria rigida</i>	Big galleta
<i>Palafoxia arida</i> var. <i>gigantea</i> * <sup>†</sup>	Giant Spanish needles
<i>Panicum urvilleanum</i>	D'Urville's panic grass
<i>Petalonyx thurberi</i>	Sandpaper plant
<i>Pholisma sonora</i> *	Sand food
<i>Tiquilia plicata</i>	Pleated crinklemat
*Special status plants; <sup>†</sup> Dominant species	

Common associated species with *Astragalus magdalenae* var. *peirsonii*  
in the Algodones Dunes.

## Algodones Dunes Rare Plant Surveys

### Peirson's Milkvetch

*Astragalus magdalenae* var. *peirsonii*

Site No. \_\_\_\_\_ Area 1 2 3 Date \_\_\_\_\_ Apr. 2004

Investigators \_\_\_\_\_

\*\*\*\*\*

No. of *Apr. 2004* seedlings \_\_\_\_\_

No. of *Feb. 2004* seedlings \_\_\_\_\_

No. of *Nov. 2003* plants / reprod. \_\_\_\_\_ / \_\_\_\_\_

No. of *Feb. 2003* survivors / reprod. \_\_\_\_\_ / \_\_\_\_\_

No. of *perennial (pre-2003)* survivors / reprod. \_\_\_\_\_ / \_\_\_\_\_

No. of plants damaged by OHV activity:

Seedlings \_\_\_\_\_

Perennial \_\_\_\_\_

**Algodones Dunes Rare Plant Surveys**  
**Peirson's Milkvetch**  
*Astragalus magdalenae* var. *peirsonii*

Site No. \_\_\_\_\_ Area    1    2    3    Date \_\_\_\_\_

Investigators \_\_\_\_\_

\*\*\*\*\*

No. of Feb. 2004 seedlings \_\_\_\_\_

No. of Nov. 2003 seedlings \_\_\_\_\_

Per cent of Nov. 2003 plants reproductive \_\_\_\_\_

No. of Feb. 2003 survivors \_\_\_\_\_

No. of Feb. 2003 plants reproductive \_\_\_\_\_

No. of perennial (pre-2003) survivors \_\_\_\_\_

No. of perennial survivors reproductive \_\_\_\_\_

No. of plants damaged by OHV activity:

Seedlings \_\_\_\_\_

Perennial \_\_\_\_\_